

FORENSIC DETERMINATION OF WRITING AND PRINTING ORDER: INKJET AND THERMAL PRINTERS WITH BLACK AND BLUE INKS

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INTRODUCTION

Determining the chronological order of printed and handwritten text is a critical area in forensic document examination. This study investigates how different printer technologies (inkjet and thermal) and ink colors (blue and black) affect writing order detection. Our goal is to uncover manipulations used in document forgery cases [1,2].

AIMS

- . To determine the relationship and writing order between printed text from inkjet and thermal transfer printers and handwriting.
- . To reveal how black and blue inks affect layer differentiation and writing order determination.
- . To demonstrate the effectiveness of the ForenScope Superspectral forensic imaging device in these examinations.

MATERIAL AND METHODS

In this study, two different printer technologies were used: inkjet and thermal transfer. Standard A4 office paper was used for the inkjet printer, while thermal paper was used for the thermal transfer printer.

- . **Scenario 1:** Signature applied before printing.
- . **Scenario 2:** Signature applied after printing.

All prepared samples were examined using the ForenScope Superspectral forensic imaging device, which provides multi-wavelength imaging and enables layer differentiation.

RESULTS

The ability to determine the writing sequence varies depending on printer technology and ink color.

- . **Inkjet Printers:** A clear layer difference was observed between handwriting and printing, which allowed for successful determination of the writing order.
- . **Thermal Printers:** Layer separation was not possible with thermal printing, proving this technology to be a limitation in forensic analysis.
- . **Ink Effect:** Blue ink provided a more distinct layer separation compared to black ink. The ForenScope Superspectral device enhanced this visibility.

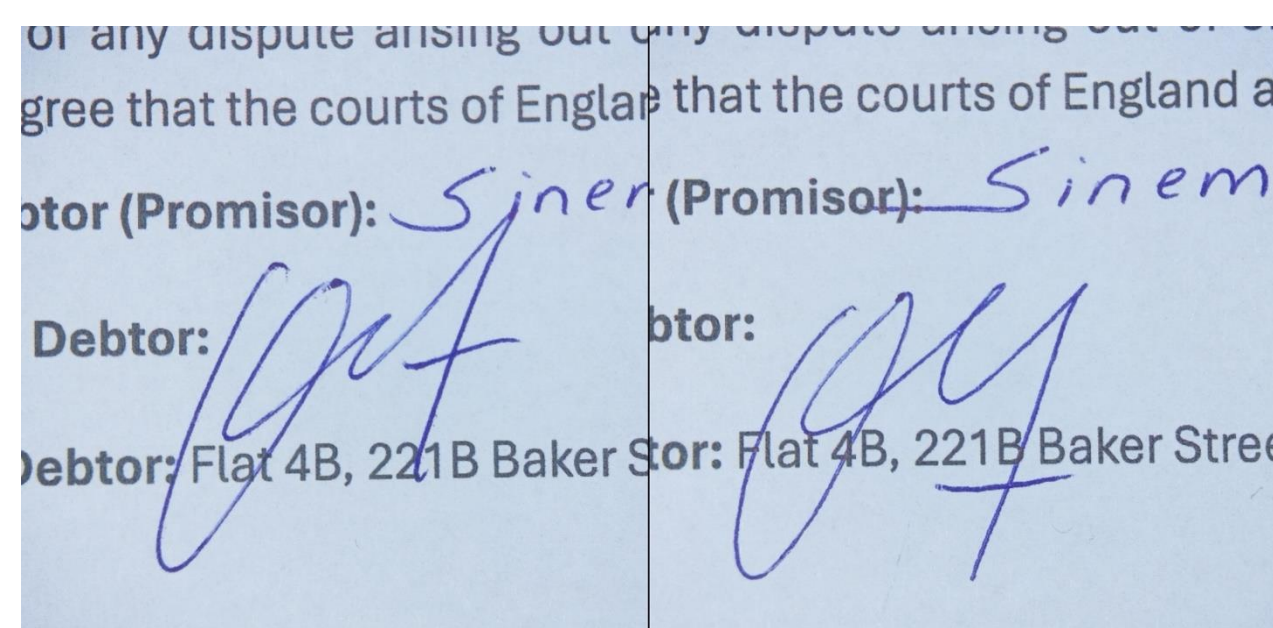


Figure 1: Blue Ink Comparison

Taken with the ForenScope Superspectral device on A4 paper with an inkjet printer, these photos compare documents where the signature was applied first on the left, and printing was done first on the right, under a white light.

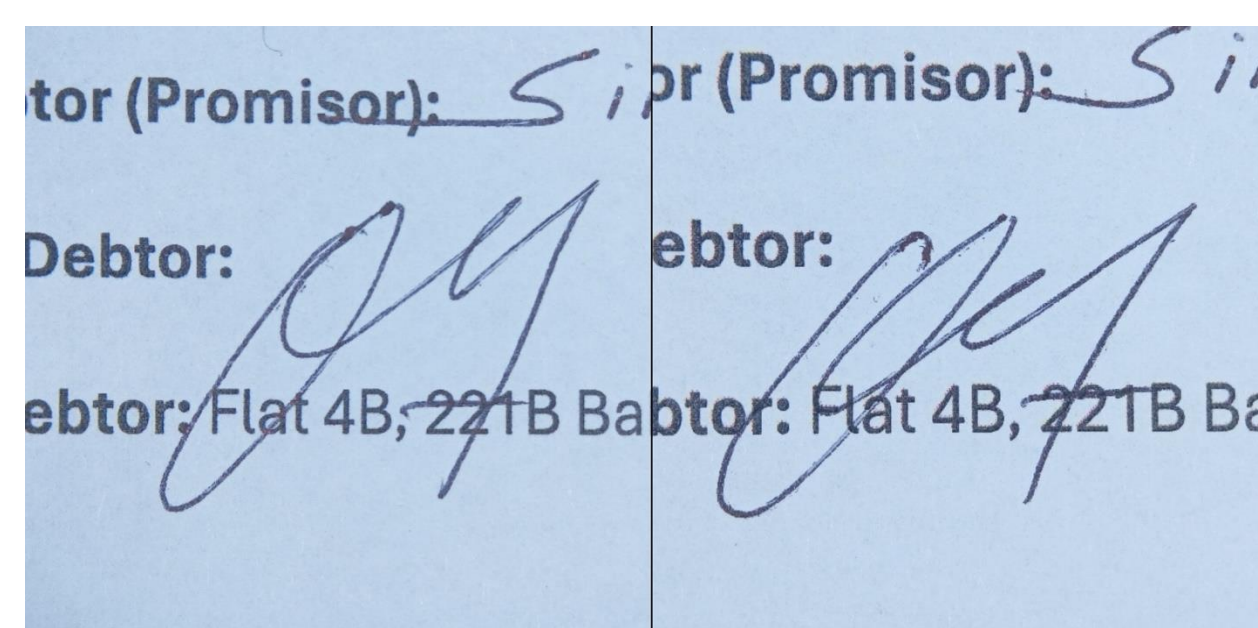


Figure 3: Black Ink Comparison

Taken with the ForenScope Superspectral device on A4 paper with an inkjet printer, these photos compare documents where the signature was applied first on the left, and printing was done first on the right, under a white light.

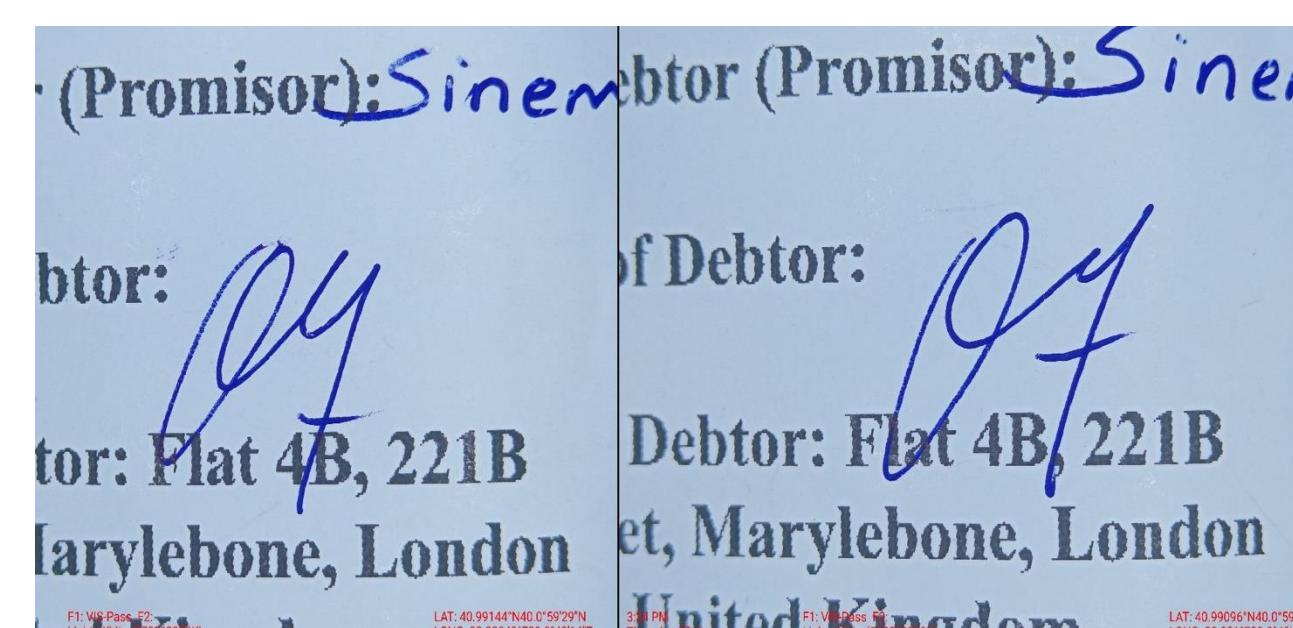


Figure 5: Blue Ink Comparison

Taken with the ForenScope Superspectral device on thermal paper with a thermal printer, these photos compare documents where printing was done first on the left, and the signature was applied first on the right, under a white light.

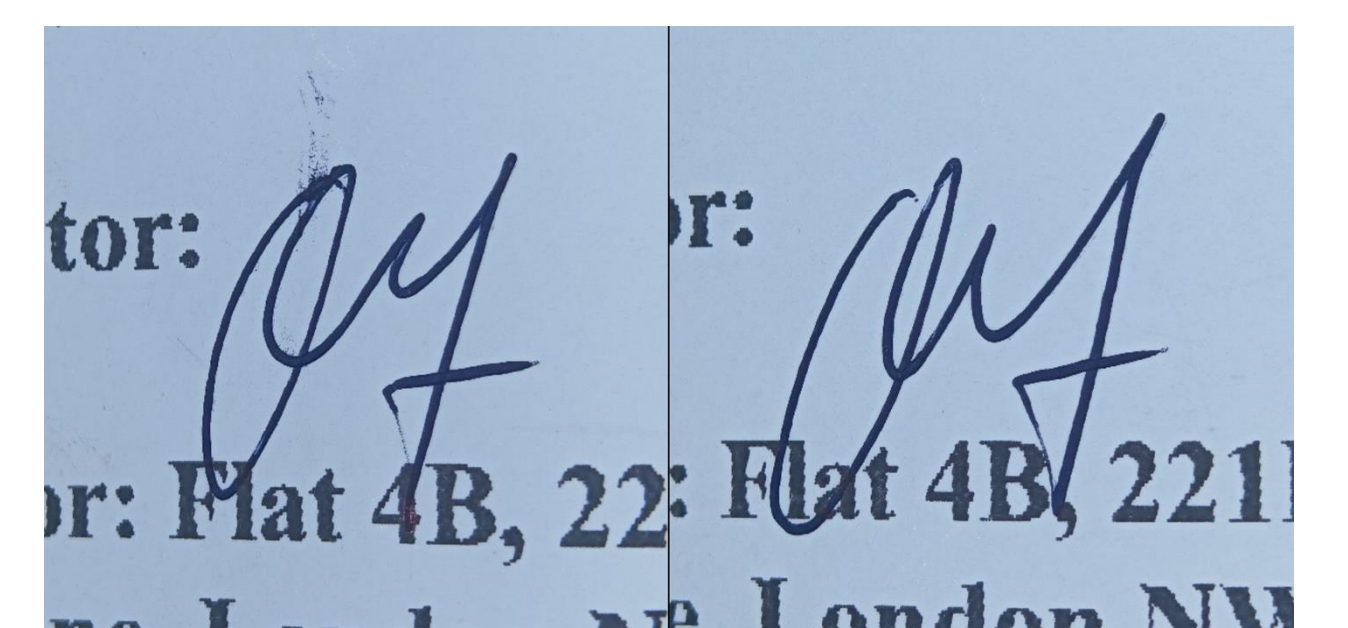


Figure 7: Black Ink Comparison

Taken with the ForenScope Superspectral device on thermal paper with a thermal printer, these photos compare documents where the signature was applied first on the left, and printing was done first on the right, under a white light.



Figure 2: Blue Ink Comparison

Taken with the ForenScope Superspectral device on A4 paper with an inkjet printer, these photos compare documents where the signature was applied first on the left, and printing was done first on the right, under green light and an LP715 filter.

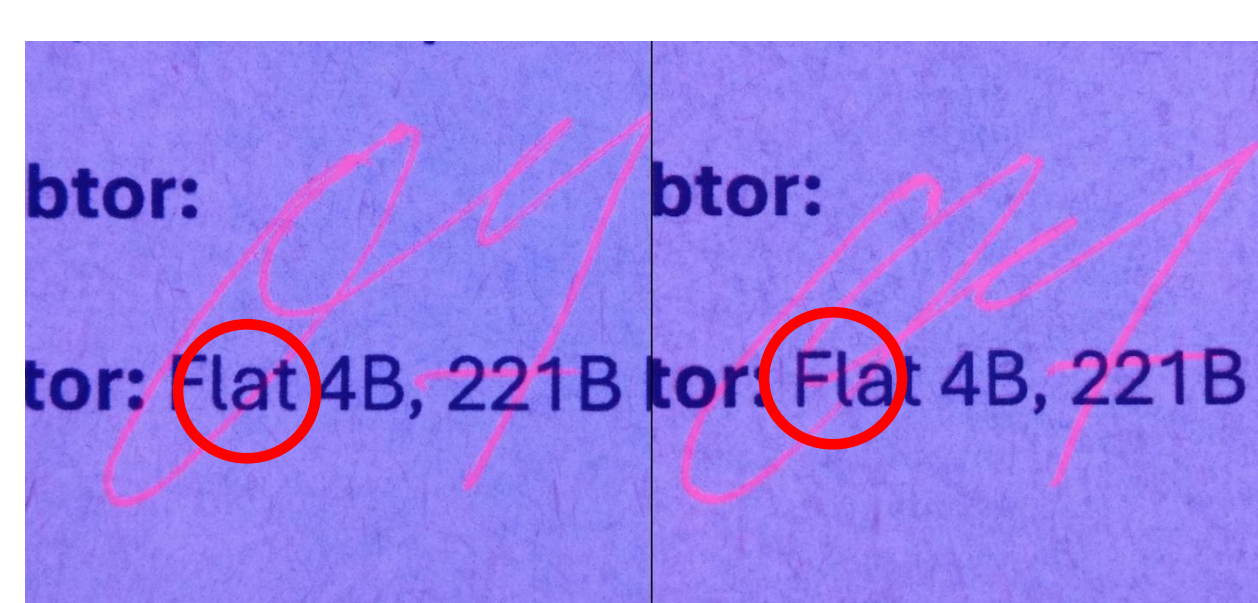


Figure 4: Black Ink Comparison

Taken with the ForenScope Superspectral device on A4 paper with an inkjet printer, these photos compare documents where the signature was applied first on the left, and printing was done first on the right, under UV-A light and an LP715 filter.

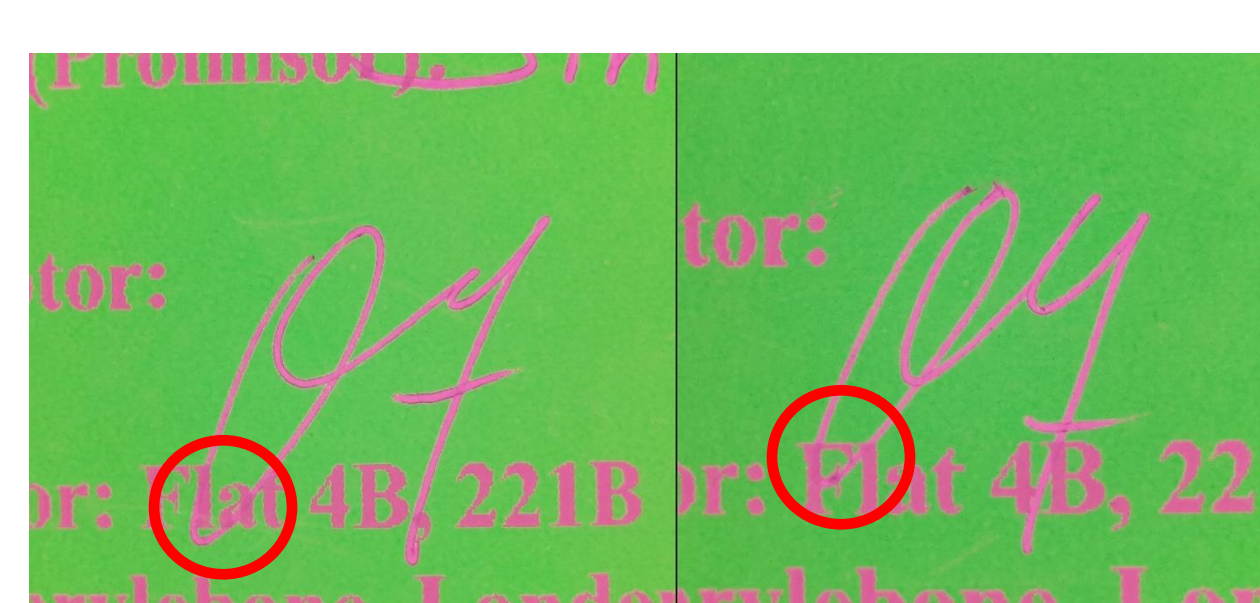


Figure 6: Blue Ink Comparison

Taken with the ForenScope Superspectral device on thermal paper with a thermal printer, these photos compare documents where printing was done first on the left, and the signature was applied first on the right, under a green light and an LP715 filter.

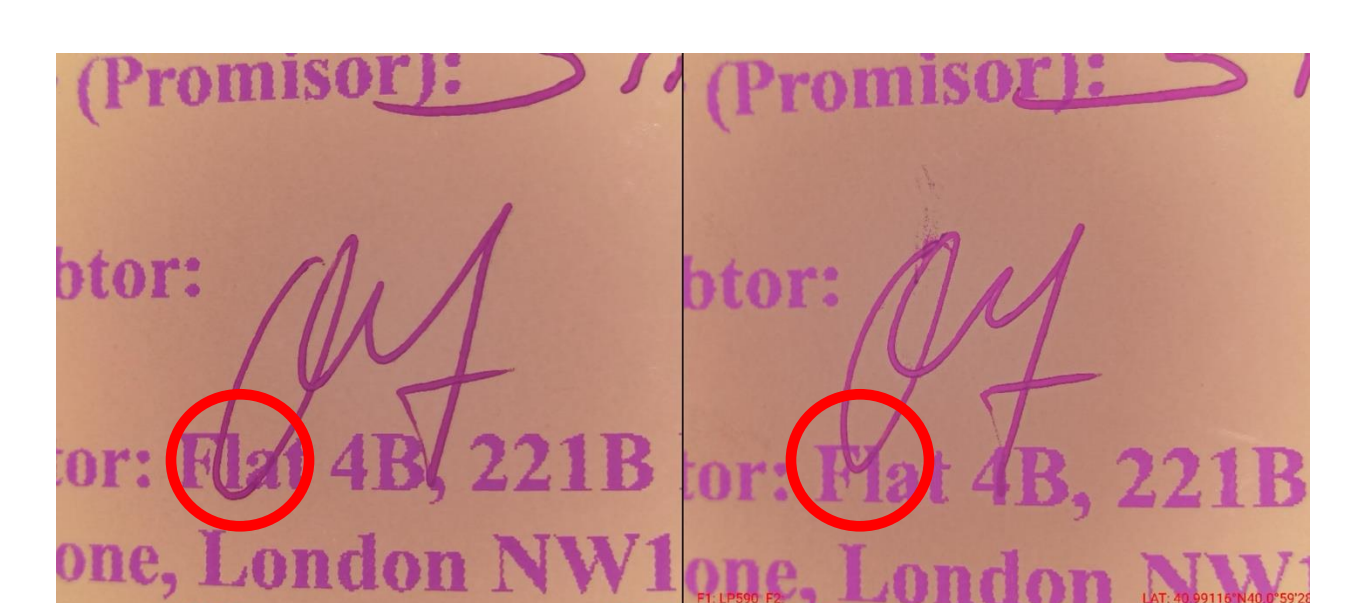


Figure 8: Black Ink Comparison

Taken with the ForenScope Superspectral device on thermal paper with a thermal printer, these photos compare documents where the signature was applied first on the left, and printing was done first on the right, under cyan light and an LP590 filter.

DISCUSSION AND CONCLUSIONS

Our study shows that printer technology and ink color are key factors in determining the sequence of writing.

- . **Inkjet Printers:** A clear layer difference between handwriting and print was observed. This determination was made by analyzing the physical interactions between the two ink layers, such as one ink overlapping or intermixing with the other, which allowed us to successfully determine the writing order.
- . **Thermal Printers:** Layer separation was not possible with these printers, proving this technology to be a limitation in forensic analysis.
- . **Ink Color:** Blue ink provided a more distinct layer separation than black ink, and the ForenScope Superspectral device enhanced this visibility.

In conclusion, both printer type and ink color are of critical importance for determining writing order in forensic document examinations.

REFERENCES

- [1] Martins, A. R., Dourado, C. S., Talhavini, M., Braz, A., & Braga, J. W. B. (2019). Determination of the chronological order of ballpoint pen cross-lines with hyperspectral imaging in the visible range and multivariate analysis. *Forensic Science International*, 296, 91–100.
- [2] Silva, C. S., Borba, F. S. L., Pimentel, M. F., Pontes, M. J. C., Honorato, R. S., & Pasquini, C. (2013). Classification of blue pen inks using infrared spectroscopy and linear discriminant analysis. *Microchemical Journal*, 109, 122–127.

Common Security Inks of Valuable Documents and One-to-Many Techniques

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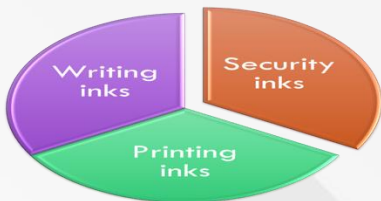
✓ Ink definition

- Ink is a liquid (semi-liquid) or paste material that contains a special kind of colorant used mostly for writing, printing, and drawing.
- A colloidal system of fine pigment particles dispersed in a solvent.

✓ Main Ink Ingredients



✓ Common ink types



✓ Concise Terms of Inks Security



✓ Classification of Security Inks IRIDESCENT INKS

I. 1. Iridescent ink



I. 2. Color shifting inks/ OVI



I. 3. Optically variable magnetic ink (spark, ovmi)



I. 4. Metallic ink



II. NON-IRIDESCENT INKS

II.1. IR- Inks

II.1.1. IR-FLUORESCENT INKS



II.1.2. IR-METAMERIC INKS



II.1.3. Anti-Stokes Ink

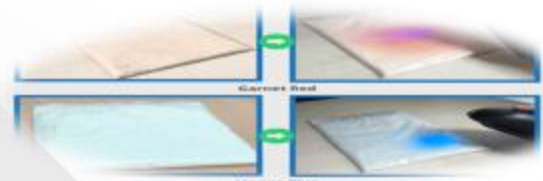


II.2. UV- Inks

II.2.1. UV Fluorescent inks



II.2.2. Photochromic Ink



II.2.3. UV Reactive Inks



III. Special Ink

III.1. Magnetic Ink



III.2. PENETRATING INK (BLEEDING INKS)



III.3. Thermochromic Ink



DETECTION OF VOLATILE INKS USED IN FORGERY WITH A MOBILE FORENSIC IMAGING DEVICE

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Introduction

Volatile inks (thermal inks) are a new-generation forgery method used by forgers. Thermal inks become invisible when exposed to a certain temperature, and new text can be written over them. Standard visible-light sources are sometimes insufficient to detect this type of forgery. This study aims to detect volatile inks by using the specific light wavelengths and filter nanometer settings of a mobile document examination device. [1, 2]

Aims

To examine the visibility of black, red, and blue volatile (thermal) inks under different light and filter combinations.
To assess whether differences between two inks can be observed when new text is written over an area where thermal ink has been erased.
To propose the use of the ForenScope DocEX Tablet for detecting document fraud involving thermal ink.

Material and Methods

Black, red, and blue thermal inks were applied to 120 g/m² 100% cellulose A4 paper. After heating, the writings became invisible. Non-volatile inks of the same colors were then used to overwrite the same areas. The samples were examined using the ForenScope DocEX Tablet, with various light and filter combinations. Images were captured to evaluate ink visibility and differences.

Results

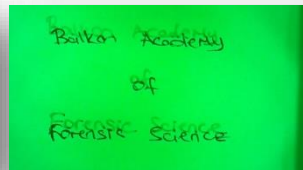
Using the light and filter combinations of the ForenScope DocEX Tablet, the invisible volatile (thermal) inks were successfully made visible and directly imaged with the device.

- ✓ **Red volatile (thermal) ink:** Successfully visualized.
- ✓ **Blue volatile (thermal) ink:** Successfully visualized.
- ✓ **Black volatile (thermal) ink:** Successfully visualized.

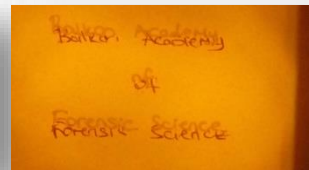
Images of red volatile (thermal) ink and non-volatile ink



White light & VIS Filter

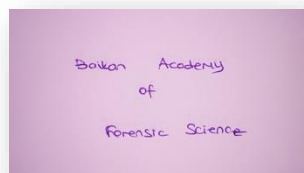


UV-B Light & BP532 Filter

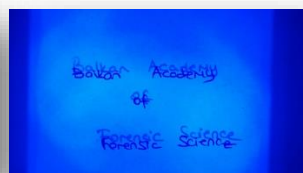


UV-B Light & LP590 Filter

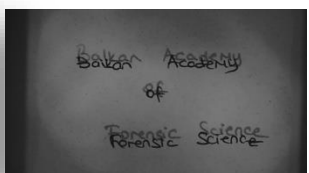
Images of blue volatile (thermal) ink and non-volatile ink



White light & VIS Filter



UV-B Light & VIS Filter

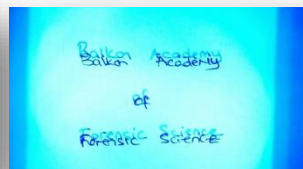


UV-B Light & VIS Filter with Monocolor

Images of black volatile (thermal) ink and non-volatile ink



White light & VIS Filter



UV-B Light & VIS Filter



UV-B Light & LP590 Filter

Discussion and Conclusions

Our study demonstrated that volatile inks can be made visible using low-nanometer UV light and various filter combinations.

- ❑ Text written with red volatile ink and made invisible by heat exposure was made visible again using the ForenScope DocEX Tablet.
- ❑ Text written with blue volatile ink and made invisible by heat exposure was made visible again using the ForenScope DocEX Tablet.
- ❑ Text written with black volatile ink and made invisible by heat exposure was also made visible using the ForenScope DocEX Tablet.

The most significant common finding in this study is that UV-B light played a crucial role in the detection of volatile inks. Volatile (thermal) inks that were previously reported as undetectable under visible light, IR light, and 360 nm UV-A light became visible under low-nanometer UV-B light.

These results indicate that the ForenScope DocEX Tablet is highly effective in detecting this type of document forgery.

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Medically Assisted Suicide in Italy: A Forensic and Bioethical Analysis After Constitutional Court Ruling n. 242/2019

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INTRODUCTION

Following the landmark ruling No. 242/2019 of the Italian Constitutional Court, physician-assisted suicide (PAS) was deemed legally non-punishable, albeit under strict conditions, despite the absence of comprehensive national legislation. In this context of legislative inaction, requests for access to PAS have increased, exposing regional healthcare systems as unprepared to implement adequate procedural measures. This lack of uniformity has resulted in disparities in access, uncertainty regarding procedural pathways, and potential risks for both the protection of patient rights and the legal safeguards of healthcare professionals. The present study aims to examine, from a forensic and bioethical perspective, the real-world application of the legal criteria established by the Court, to identify systemic inconsistencies, and to contribute to the development of a uniform regulatory framework capable of ensuring equity, transparency, and respect for human dignity in end-of-life care.

METHODS

A retrospective observational design was adopted, focusing on 12 documented requests for PAS, collected and analyzed by three major Italian Institutes of Legal Medicine: Trieste, Rome, and Salerno. Data collection encompassed detailed clinical records, formal petitions, advance healthcare directives (DAT), multidisciplinary assessments, opinions from territorial ethics committees (CETs), public court rulings, and relevant media reports. Each case was analyzed with respect to primary and comorbid diagnoses, disease duration, ongoing pharmacological and palliative treatments, degree of dependency on life-sustaining therapies or caregiver support, response times from local health authorities and CETs, and the final procedural and legal outcomes. Special attention was devoted to the interpretation of the “life-sustaining treatment” criterion, which emerged as a point of divergence between technical commissions and ethics committees, largely due to the absence of a universally accepted definition.

RESULTS

The demographic, clinical and legal characteristics of the included patients are summarized in Table 1. Statistical analysis revealed no significant differences between the groups with positive or negative judgments regarding access to PAS in terms of ongoing palliative care ($\chi^2 = 0.090$, $df = 1$; $p = 0.764$) or pain control ($\chi^2 = 1.440$, $df = 2$; $p = 0.487$). However, a robust correlation was identified between the recognition of dependence on LSTs and the assessment of access to PAS ($\chi^2 = 9.000$, $df = 1$; $p = 0.003$). Despite clear patient requests and ethical justification, only one PAS procedure was carried out within the Italian healthcare system. Four additional cases, although formally approved, were not executed due to bureaucratic delays and procedural ambiguities. The remaining requests were still unresolved at the close of the study period. The “life-sustaining treatment” criterion proved to be a major source of interpretative variability, with differing positions between technical commissions and CETs, resulting in inconsistent application of eligibility requirements. Extended timelines and the absence of defined procedural deadlines further hindered the effective implementation of PAS.

Table 1. Demographic, clinical, and legal characteristics of the sample		
Variable	N	n (%); mean ± SD
Sample size	12	—
Gender (female)	12	7 (58.3%)
Age (years)	12	58.25 ± 12.32 (Min = 45; Max = 83)
Years between diagnosis and request for PAS access	11	16.45 ± 15.95 (Min = 1; Max = 55)
Main diagnosis	11	Neurological: 8 (66.7%) Onco-hematologic: 3 (25.0%) Other: 1 (8.3%)
Comorbidities	11	None: 2 (18.2%) 1–2: 7 (63.6%) ≥3: 2 (18.2%)
Pain control	10	Yes: 6 (60.0%) No: 3 (30.0%) Partial: 1 (10.0%)
Ongoing palliative care	10	Yes: 6 (60.0%) No: 4 (40.0%)
Care needs	10	None: 1 (10.0%) Human only: 3 (30.0%) Instrumental only: 2 (20.0%) Human and instrumental: 4 (40.0%)
Advance directives present	10	Yes: 8 (80.0%) No: 2 (20.0%)
Recognition of dependence on LSTs	9	Yes: 5 (55.6%) No: 4 (44.4%)
Final decision for PAS access	9	Yes: 5 (55.6%) No: 4 (44.4%)
LST=Life-Sustaining Treatments; PAS=Physician-assisted suicide		

CONCLUSIONS

The findings highlight the complexity of translating judicial principles into consistent clinical practice in the absence of legislation. Although about two-thirds of PAS applicants received palliative care (PC), they still requested PAS, suggesting that PC alone cannot address concerns such as loss of independence and autonomy. Our study indicates that neither PC nor pain control effectively mitigates these fears, and no significant differences emerged between patients receiving or not receiving such care in CET feasibility assessments. Variability in the interpretation of eligibility criteria and procedural delays further generate inequities among patients with comparable clinical profiles. This raises medico-legal concerns, jeopardizing both patient self-determination and the legal protection of healthcare professionals. Bioethically, the lack of standardized criteria and shared tools undermines transparency and equity, potentially eroding public trust. A national law is urgently needed to define eligibility, standardize evaluations, set procedural timelines, and provide legal safeguards, thereby ensuring equitable access, transparency in decision-making, and respect for dignity and self-determination. The study’s conclusions seek to inform legislative initiatives and contribute to the development of standardized procedures, offering a model for other jurisdictions facing similar regulatory gaps.

